# ALASKA'S ICE ROADS AND INVESTMENT DECISION IN DRILLING:

# AN EMPIRICAL ANALYSIS

By

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Abstract

This thesis applies Autoregressive Distributed Lag modeling techniques to estimate the effects of ice road season lengths on exploration activities in Alaska within the North Slope. This analysis uses data on winter off-road travel from 2001-2018 in monthly intervals against exploration wells spudded. It is found that while ice roads do not affect overall drilling activities in the North Slope, the lengths of the season plays significant part in exploration of new fields. While this subject has become a popular subject due to variations in the ice road season, no similar statistical analysis has been conducted to date. Oil prices, production and Alaska's oil policy were also found to be important variables in characterizing exploration activity.

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To my husband

for his patience, his unconditional love and his support.

To my family,

both by blood and by law,

this would not have been possible without each one of you.

Thank you.

# Chapter 1 Introduction

Alaska is a state that is highly dependent on the oil industry. Beginning in the early 20th century, the discovery and commercialization of oil fields has generated income for the state. The state levees no personal income or sales taxes, residents receive Permanent Fund Dividends[1] and the state administers a variety of entitlement programs, all made possible due to the oil wealth redistributed by the state government. Oil and gas production provided 54.5 percent of the total revenue distributions for the state for the fiscal year of 2018 which saw a total of $796.9 million in state oil revenue[2] (Alaska Department of Revenue, 2018b). Alaska is home to the one of the world's largest pipeline systems, the Trans Alaska Pipeline System (TAPS), an 800-mile-long pipeline that allows oil producers to send the North Slope's crude oil through to the ports of Valdez.

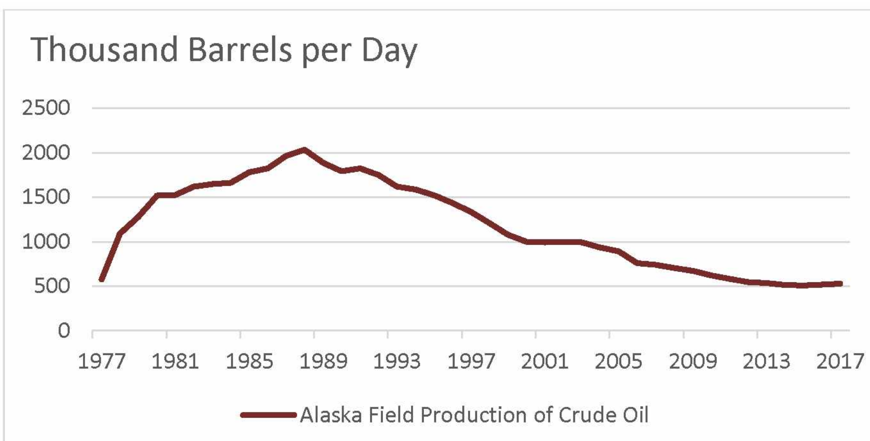


**Figure 1: Alaska Field Production of Crude Oil. Source:** (Alaska Department of Natural Resource, 2017)

[1] The Permanent Fund Dividend (PFD) is a dividend paid to Alaska residents. The fund is primarily funded by Alaska's oil revenue and is managed by Alaska Permanent Fund Corporation (APFC), a government instrumentality of the State of Alaska created to manage and invest the assets of the Alaska Permanent Fund.

[2] The tax is based on the net value of oil and gas, which is the value at the point of production multiplied by the taxable volume, less all lease expenditures including certain qualified capital and operating expenditures. The current tax rate is at 35% of the production tax value.

While the pipeline is able to accommodate up to 2 million barrels of oil a day, production of oil from the North Slope has steadily declined since 1988 and for 2018 and is only transporting an average of 508.6 thousand barrels per day as shown in Figure 1, (Alaska Department of Revenue, 2018a). Low volume of oil production is certainly alarming – the pipeline requires a minimum of 350 thousand barrel per day to operate safely and if production continues to decline the pipeline could shut down altogether, cutting off Alaska's oil revenues.

It is currently estimated that oil available Prudhoe Bay is the largest in the United States, with reserves at an estimated 25 billion barrels of oil. The field is operated by British Petroleum (BP) with partners ExxonMobil and ConocoPhillips Alaska.

Before a rig is commissioned and drilling occurs, operators complete a full geological analysis of the acres leased. Once an area is deemed to be commercially viable, a well pad is constructed, and an exploration hole is drilled. The permafrost present in Alaskan drilling causes problem as the bit and drilling fluids melt the permafrost, creating an instable top hole. After reaching a target depth, the drill pipes are removed, and a casing is placed in and cemented. A BOP[3] is installed and the well can now be perforated to start producing. Operators can then choose to pursue to develop the drill pad to drill more wells and develop the current field.

Environmental requirements that have been set by the state prohibits damage to the tundra by means of restricted pathways via either gravel roads or ice roads. The exploration activities peak in winter for the North Slope as the ice roads make conditions satisfactory to transport rigs and provide logistical support for the slope for areas that do not have gravel roads

[3] BOP is a blowout preventer. BOP typically has three different preventers stacked including pipe rams, blind rams and shear rams and is used to control the well.

in place. Offshore drilling activities at the Cook Inlet are the opposite, as drilling mostly occurs during summer.

Although trends in world energy prices are difficult to predict (Ghosray & Johnson, 2010), the aim for this paper is two-fold; to explore the dynamic relationship between changes in the rig counts to oil prices and whether one particular unique feature, the ice road, plays a crucial part in the exploration activities in Alaska. State economists have predicted that the state would require the price of crude oil to be at $91 per barrel to fill the hole in the state's budget (McChesney, 2018), making the response in rig counts to the volatile oil prices and explaining the asymmetry present in Alaska's exploration levels crucial for state planning.

With the new tax bill[4] allowing for drilling in the Arctic National Wildlife Refuge (ANWR), Alaska Senator, Lisa Murkowski hopes to entice investors to explore the region. The State of Alaska currently offers leases for state owned acreage in the North Slope with governmental powers to regulate the entire oil and gas extraction cycle. Most leases have multiple corporations' investment and different working interest. Drilling currently occurs at three distinct locations in Alaska, the Cook Inlet, the North Slope and the Arctic Ocean.

Another repercussion of the decline in oil prices would be the total population of Alaska. Immigration to and emigration in Alaska has been dependent on the oil cycles and military activity since the 1980s and the oil bust in 2014 has proved the same. The population declined slightly by one third of a percent in 2017 to 737,080 people; the first reduction in population in decades.

[4] The Tax Cuts and Jobs Act of 2017 was signed by President Trump in December 2017. Title II of the bill opens 1002 area of ANWR up for drilling.

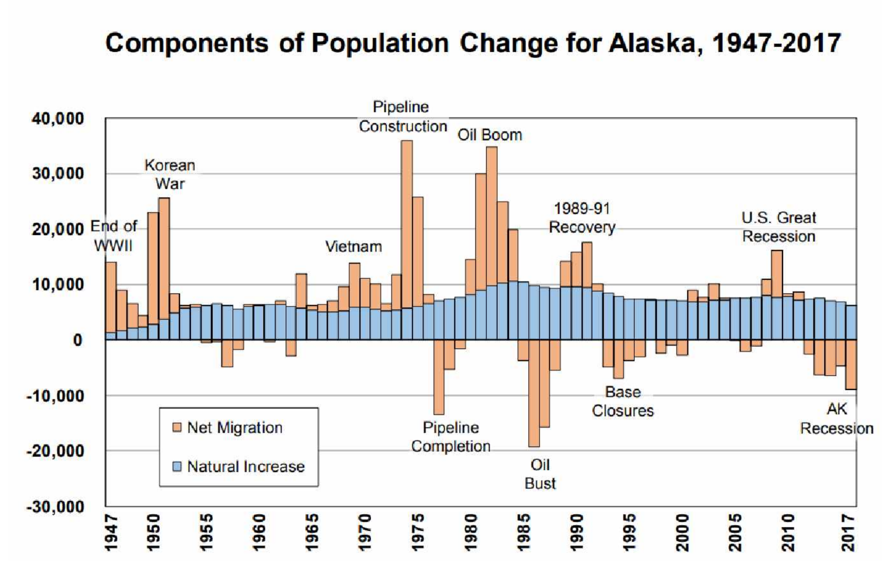


**Figure 2: Components of Population Change for Alaska, 1947-2017. Source: (Department of Labor and Workforce Development, 2018)**

For the state of Alaska, the workforce declined by 1.9 percent, to 416,459 in 2017 and employment in the oil and gas industry has been strongly affected by the oil prices. Fascinatingly, there was no significant reduction in employment in the oil and gas industry in Alaska until 2016, where the total number of workers in the oil industry fell 16 percent, close to a year after the price of oil declined by 49 percent.

One side effect of migration out of the state is that although unemployment grew by 0.3% in the years 2016-2017, the percentage of nonresidents in the oil and gas industry increased from 36 percent to 37.1 percent. Even though residents represented just fewer than 63 percent of oil and gas workers, they were 70 percent of the total decline (Department of Labor and Workforce Development, 2018). This is considered a leakage to Alaska's economy as the non-resident workers leave with their income and will not contribute to the state. The state currently has no income taxes on their earnings and non-residents pay to the state of their residence instead.

# Chapter 2 Background

## 2.1 Boom and Bust Cycles of Oil Prices and Drilling

Beginning of the last quarter of 2014, the oil and gas sector underwent a bust, with number of rigs falling 49 percent in the first six months and a decline of 54 percent in oil prices. As of April 2018, the price of Alaska North Slope (ANS) West Coast crude oil has rebounded to $72.94 per barrel, from the bottom price of $26.23 per barrel in January 2016. Such boom and bust cycles are not uncommon in the oil and gas industry, nor are the subsequent decline in rigs. Crude oil prices have dropped sharply six times from 1981 to 2009, and reactions along with the decline of oil prices comprises of a decline in exploration and drilling.

Each boom and bust cycle had unique circumstances depending on the supply and demand factors. The current oil bust cycle is a close mirror of the 1985-1986 bust where the U.S. was not in recession, price collapsed by 58 percent and rig counts dropped by 60 percent due to an oil glut (Wilkerson, 2015). Alaskan drilling contributed to the glut in the 1980s when the Prudhoe Bay Oil Field entered peak production and providing 2 million barrels per day of crude oil.

However, this current oversupply is due to the share-maximization policy by Saudi Arabia and the technological advances in shale oil extraction, particularly hydraulic fracturing, which has transformed the United States to a position of net oil exporter. The 1980s saw only 7 months of price decline whereas the 2014 cycle saw 16 months of price decline.

Production in Alaska has steadily declined since the 1980s, even with the volatility of oil prices that have seen oil prices reach $125 per barrel.

## 2.2 Oil Tax Policy in Alaska

The government's fiscal policy has always impacted the exploration and production of crude oil in the North Slope and the Cook Inlet. After fifty-one years of gross value oil and gas production tax, in 2007 Alaska's legislature enacted Alaska's Clear and Equitable Share Act (ACES) which taxed operators at the production point and aimed to increase the state's share of benefits from the oil and gas profits.

To entice investors, ACES also offers 20 percent tax credit for qualified capital expenditures. Ever since, there has been 11 major policy changes in regard to petroleum production taxation. In 2013, Senate Bill 21 (also known as More Alaska Production Act, MAPA) was introduced to tackle both lower production and tax credits issues that were in effect due to ACES. Some of the tax credit policy change includes repealing the capital expenditure for North Slope oil and gas activities and a gross value reduction for a certain percentage of "new oil". In 2017, Governor Bill Walker signed HB 111 into law which further limits tax credits and places a minimum floor on production tax (Weissler, 2017).

The ACES legislation implemented has shown to be 'significantly detrimental with a lasting effect on exploration levels while in effect' as changing severance tax rates does not alter production rate, but tax credits does (Tappen, 2014). The tax policy more than tripled the tax liability for the producers (Reimer, Guettabi, & Tanaka, 2017). Changes in Alaska's oil production tax policy are an important variable in this study as investment spending highly affects exploratory drilling activities. Optimal oil extraction in Alaska is governed by the tax policy and specifically in Alaska; evidence suggests that the structure of the tax policy can create an optimal production path at the expense in net social benefit (Leighty & Lin, 2012).

### 2.3 Ice Road Transportation

Ice is an effective and economical means to support load and is profoundly used as the material of choice for road constructions in transporting rigs to and on the North Slope. Apart from being economical, ice roads have incredible salient features such as being environmentally friendly and leaves little footprint over the seasons and protects the tundra (Masterson, 2009). Currently, ice roads are constructed and maintained by Alaska's Department of Natural Resources and operating companies with different areas open for travel at different, staggered dates.

One major drawback of using ice roads is the seasonality of it. Alaska is among the fastest warming places on Earth and the length of tundra travel dates reflect extensive warming of the Interior region (McNeely & Shulski, 2011). There is a shift in winter and spring temperatures which negatively affect the length of the ice road seasons which can be attributed to climate change.

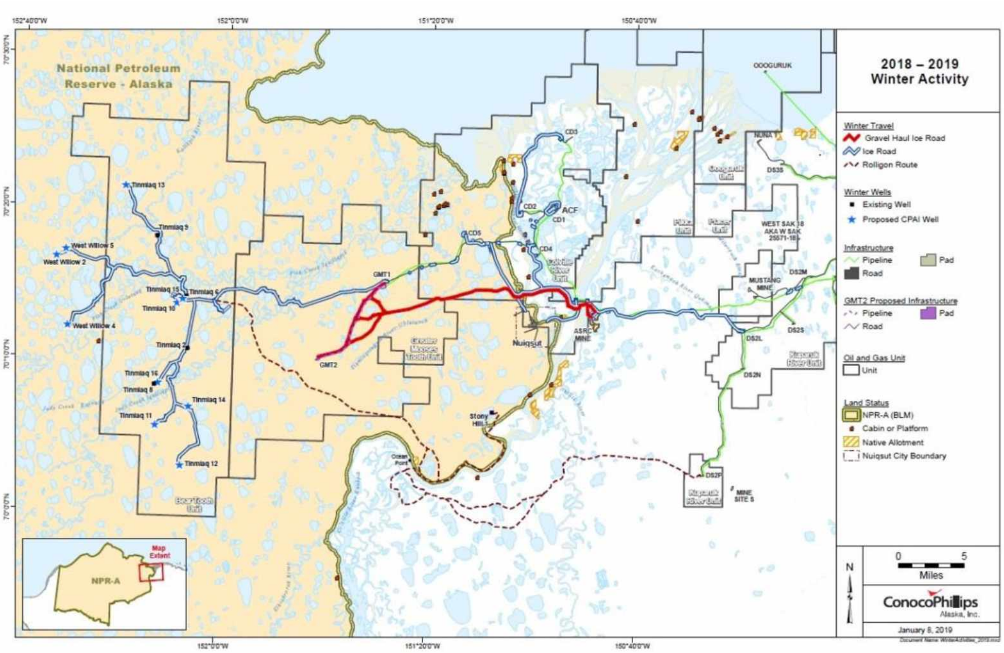


**Figure 3: Network of Ice Roads in NPR-A. Source: (ConocoPhillips Alaska, 2018)**

The shorter seasons for ice roads both on land and rivers raises the cost for exploration activities. As seen in Figure 3, companies utilize the ice road to find new prospects where a pad is then built, and subsequently a well is drilled. Once a company makes a full assessment of the geological surveys, they could then choose to develop the pad and introduce a gravel road to the pad for continuously drilling if deemed economical. Such gravel roads, as seen in the picture costs significantly higher. While ice roads are estimated at $100,000 per mile, constructing and maintaining a gravel pad is close to $2 million per mile. Operating companies lease the land and are required to be able to restore the environment as if untouched once their lease is up.

Ice road transportation does not only serve the oil and gas industry. It is also one of methods of transportations used by communities living in remote areas and without which, increases the cost of living for the people in these areas. Shorter ice road seasons damages economic activity for Alaska and will cost the state an estimated $10-$20 million per year (Berman & Schmidt, 2018).

# Chapter 3 Literature Review

The primary paper referred to model the lag that exists in Alaska's oil economy is by Khalifa, Caporin and Hammoudeh (2017). The data used in their paper are rig counts, rig productivity and oil prices for over ten different subsamples measured in five different time periods. The authors first pieced correlations between changes in rig count and changes in rig productivity using the Vector Auto Regressive model with exogenous variables (VARX), estimating a dynamic relationship between these two target variables and settling for a linear model as deemed appropriate. A second dynamic relationship is then established using the VARX model between the oil price and the changes in rig count. Three different lags are included in the models (1, 2 and 3 quarter lags) to evaluate the responsiveness of the rig counts to the changes in oil prices.

According to the study's findings, the authors found that not only that the change in rig productivity is almost never significant on the rig counts, lags of 2 and 3 quarter lags are also insignificant in rig count suggesting that the relationship between oil prices and rig counts are delayed by only one quarter lag. This relationship is of a significant interest to analysts, investors, oil companies and policy makers (amongst others), showing that changes in oil prices are not immediately reflected in changes in rig count or productivity (Khalifa, Caporin, & Hammoudeh, 2017).

Another approach to estimating the lag is to use futures prices as the 'market-determined certainty equivalent prices' (Chen & Linn, 2017). In the paper, the authors find that investments respond to futures prices and the lag between changes in futures prices and changes in drilling activity does occur for private independent oil companies. The study also finds that while operators opt for value maximizing choice, i.e, increase or decrease number of drilling rigs used, the lag exists due to a delay in implementation such as adjustment costs or the presence of uncertainties. This paper aims to highlight the production, the policies in place and ice road as factors of the delay in implementation.

Oil price decline in 2014 have affected all energy states in the United States of America with all states shedding between 60% of their rigs between 2014 and 2016. One peculiar oddity is that Alaska lags behind all other states and as of June 2018, was still dropping jobs while other states have begun to recover. Out of all 13 energy states, only Alaska continues to be in recession in 2018 (Guettabi, 2018). It is then important to consider the salient features in drilling in the Arctic that could have made this difference in recession and recovery.

# Chapter 4 Methodology

While the entire industry is of interest, this study focuses only data from the North Slope as drilling activities for Cook Inlet is primarily for gas that is fed to the Anchorage heating system. Previous studies have shown that there exists a contemporaneous relationship between the variables such as oil prices and rig counts. Studies from Chen & Lim models rig count as a proxy for investments that we will apply for this thesis.

## 4.1 Econometric Models

The model that is used to capture the investment decision to drill in Alaska is as below:

$$rig_t = \beta_0 + \beta_1 \log(WTI)_t + \beta_2 \log(pro)_t + \beta_3 ice_t + \beta_4 MAPA_t + \varepsilon_t \qquad (1)$$

$$explwell_t = \alpha_0 + \alpha_1 \mathrm{pos}_t + \alpha_2 \mathrm{neg}_t + \alpha_3 pro_t + \alpha_4 ice_t + \alpha_5 ACES_t + u_t \qquad (2)$$

where $rig_t$is the number of rigs in the North Slope that acts as a proxy for investment; the $\log(WTI)_t$ is the log of WTI or Brent price of crude oil, $pro_t$ is the production rate from the North Slope and is collected from Alaska Department of Revenue, $expwell_t$ is the number of new exploratory wells spudded and $ice_t$ is the dummy variable and equals 1 when the tundra travel roads are open for use. *Pos* reflects when a change in WTI oil prices are positive and *neg* reflects when a change WTI oil prices are negative and is used to see if the price increase or decrease is symmetrical for exploration. For this paper, the ice road also replaces seasonality.

From the equation, we expect a positive relationship between rig count, exploratory wells, price and production; an increase in price and production would increase the decision to invest in Alaska. Similarly, the hypothesis is that an open ice road would allow for an easier access for drilling activities and thus would be expected to be a positive factor for the implementation for the investment choice. As Alaska's tax policy heavily influences the investment decisions on the North Slope, a dummy variable for MAPA and ACES was included to show the differences in effect for before and after the bill was implemented in 2013.

### 4.2 ARDL Model

Auto-regressive distributed lag models are linear time series models where the dependent variables and independent variables are related not only contemporaneously, but across lagged variables as well. To illustrate this, the previous model is redefined as below.

$$\log(rig_t) = \beta_0 + \sum_{i=1}^{n1} \propto_1 \Delta\log(rig_{t-i}) + \sum_{i=1}^{n2} \propto_2 \Delta log(WTI)_{t-i} + \sum_{i=1}^{n3} \Delta\log(pro)_{t-i} + \delta_0\, rig_{t-i} + \delta_1 \log(WTI)_{t-i} + \delta_2 \log(pro)_{t-i} + \beta_1 ice_t + \beta_2 MAPA_t + \varepsilon_t \tag{3}$$

$$explwell_t = \alpha_0 + \sum_{i=1}^{n1} \theta_1 \Delta expwell_{t-i} + \sum_{i=1}^{n2} \theta_2 \Delta pos_{t-i} + \sum_{i=1}^{n3} \theta_3 \Delta neg_{t-i} + \sum_{i=1}^{n4} \theta_3 \Delta\log(pro)_{t-i} + \vartheta_0\, explwell_{t-i} + \vartheta_1 \mathrm{pos}_{t-i} + \vartheta_2 \mathrm{neg}_{t-i} + \vartheta_3 \log(pro)_{t-i} + \alpha_1 ice_t + \alpha_2 ACES_t + u_t \tag{4}$$

To utilize an ARDL model, we must first conduct the F-test on each variable to determine whether the variables are cointegrated and to ensure that we are not using an I(2) variable. The long-run relationship then must be determined followed by the short-run relationship.

We fully expect a dynamic relationship between rig counts, production and the price of oil and utilizing the ARDL model not only addresses the stationary issue present in the data set, but the dynamic relationship in the dependent variable as well. The ARDL model can explain the current number of rigs and exploration wells in terms of the current and past values of production and oil price as well as the past numbers of rigs and wells.

# Chapter 5 Data

For the interest in Alaska's lag in rig counts, Alaska's number of active rigs can be obtained from Baker Hughes' monthly Rig Count, rig productivity by the average throughput that runs through the TAPS operation as well as the average monthly price of West Texas Intermediate (WTI) (in 2012 U.S Dollar) as the price of oil, information that is available publicly on the U.S Energy Information Administration (EIA) website.

The rig count data, which is publicly available on Baker Hughes' website (Baker Hughes, 2019), correspondingly is used as a proxy to capture upstream oil and gas investments from October 2000 to December 2018. As it is difficult to collect data on the total investment drilling firms spend in Alaska, the number of rigs serves as a good proxy as shown in past literature review. Production, real price and rig counts are used in their logarithmic forms.

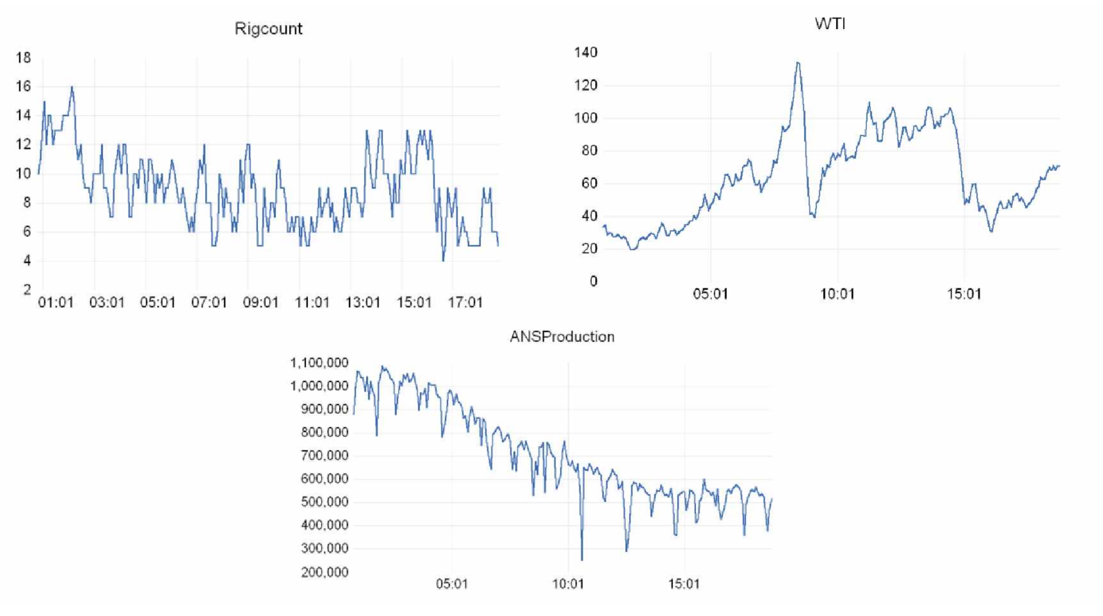


**Figure 4: Rigcount, WTI and Production rate over 18 years (217 months). Source: (Alaska Department of Revenue, 2018a)**

Opening dates are defined by the first date an area is opened to winter off-road travel and is determined when ground temperatures reach -5$^{0}$C at 30cm below the tundra surface and sufficient snow depth. This information is provided by the Department of Natural Resources under the Division of Mining, Land and Water.

To determine investment decisions for exploration in Alaska, data is collected from Alaska Oil and Gas Conservation Commission's (AOGCC) database and referenced against Alaska's Department of Natural Resources under the Division of Oil and Gas Oil and Gas Lease Ownership to determine if an exploration well was spudded each month. Wells that are spudded are considered as a decision to invest and acts a proxy instead of monetary figure for investments in Alaska. All data collected are of monthly basis beginning from October of 2000 until December 2018. Table 1 exhibits a summary of statistics for variables in real prices and leveled value and does not include dummy variables such as ice roads, ACES and MAPA.

**Table 1: Summary Statistics of Key Variables**

| Variable | Mean | Std. Dev | Min | Max |
|---|---|---|---|---|
| rig (count) | 8.926 | 2.570 | 4.000 | 16.000 |
| pro (bbls) | 706747.3 | 201199.1 | 250264.0 | 1086577.0 |
| WTI (dollars) | \$97.07 | \$8.79 | \$74.65 | \$125.55 |
| explwell (count) | 0.730 | 1.359 | 0.000 | 8.000 |

# Chapter 6 Empirical Results

## 6.1 Unit-Root Test for Drilling Activities in the North Slope

Dickey-Fuller-GLS test is chosen to check for unit root for each variable which takes as the null that a unit root is present. Table 2 summarizes the DF-GLS test and shows that there is a mixture of I(0) and I(1) variables that shows OLS is not a suitable form for regression. As ARDL model is better suited for this, the variables must show that none of the variables are I(2) variables and a DF-GLS test utilizing the first difference shows so.

**Table 2: Tests of Unit Roots Based on DF-GLS test**

| Variable | Level | | First difference | | Decision |
|---|---|---|---|---|---|
| | Test statistic | Lag | Test statistic | Lag | |
| $\boldsymbol{rig_t}$ | -4.319** | 2 | | | $I(0)$ |
| $\mathbf{log}(\boldsymbol{WTI})_t$ | -1.678 | 6 | -6.646** | 5 | $I(1)$ |
| $\mathbf{log}(\boldsymbol{pro})_t$ | -1.287 | 13 | -2.662* | 5 | $I(1)$ |
| ***explwell*** | -1.609 | 11 | -13.007** | 11 | $I(1)$ |

*Note: ** and * denote rejection of the null hypothesis of a unit root at the 5% and 10% levels, respectively. The 5% and 10% critical values for the DF-GLS statistics are -2.890 and -2.570, respectively. The lag order for the DF-GLS is selected by the Schwarz Criterion (SC).*

All lag size listed in Table 2 was determined using Schwert criterion. We fail to reject the null hypothesis of a unit root levels for all variables for all variables but rig count at 5% and 10% significance level. This suggests that that rig counts are stationary, understandably so as it costly to bring up rigs to the slope and more expensive to lay down, while prices of oil, production and exploration investments are not stationary.

6.2 Results of ice roads on overall Drilling Activities in the North Slope

The main results from Eq (3) are listed in Table 3, where short-run and long-run coefficient estimates are shown in Panel A and B with Panel C displaying the diagnostic statistics.

**Table 3: Full Information Estimate of ARDL Eq. (3)**

Panel A: Short-Run Coefficient Estimates

| Lag Order | 0 | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| Δ (Rig count) | | 0.075 | -0.053 | 0.099 | 0.182** | -0.110 |
| | | (0.074) | (0.076) | (0.076) | (0.070) | (0.067) |
| Δ (Oil price) | 0.187 | | | | | |
| | (0.159) | | | | | |
| Δ (Production) | 0.111 | 0.493*** | 0.464*** | 0.336*** | 0.194** | 0.439*** |
| | (0.097) | (0.111) | (0.116) | (0.116) | (0.116) | (0.101) |
| Ice road | 0.020 | | | | | |
| | (0.031) | | | | | |
| MAPA | 0.278*** | | | | | |
| | (0.060) | | | | | |

Panel B: Long-Run Coefficient Estimates

| Constant | Oil Price | Production |
|---|---|---|
| 10.307*** | -0.866223*** | -1.142672** |
| (1.521) | (0.424159) | (0.344407) |

Panel C: Diagnostic Statistics

| F-statistics | $EC_{t-1}$ | LM |
|---|---|---|
| 15.15 | -0.462 | 0.520357 |
| | (0.068) | |

*Notes: Numbers inside parentheses are the std errors. The upper critical bound value of the F-statistics at the 5% significance level is 5.85. LM is the Breusch-Godfrey serial correlation LM test and EC represents an error-correction term. ***,** and * represents significance at the 1%,5% and 10% levels respectively.*

As shown in Panel C, the F-statistics for the Bounds test is 15.15, exceeding even the 1% critical value for the upper bound from which we can strongly reject the hypothesis of "No Long-Run Relationship" as shown in Table 3. Not surprisingly, there is a long-run equilibrium relationship between the price of oil, the rig count and the production here in Alaska. The Akaike Information Criterion (AIC) was used to select the optimal length and is set at a maximum of six lags. The results of the Lagrange Multiplier (LM) test of residual serial correlation with a p-value of 0.520 indicates that the model fails to reject the null hypothesis of no serial correlation, suggesting that Eq.(3) is well specified with no evidence of serial correlation. The requirements for the error-correction coefficient to be negative (-0.311125) and is statistically significant is met.

In the short run, as shown in Panel A, the rig counts at a four-month lag, the crude oil production from one to five-month lag and the MAPA dummy variably is statistically significant and all have a positive coefficient as expected and is presented in Table 3. This finding suggests that an increase in production in the previous months entices operators to invest and drill more in the short-run. Surprisingly, we see that oil prices or even lagged oil prices does not affect the drilling activities in the short run as it is statistically insignificant. This could suggest operators plan their drilling activities years in advance, and a study of 12 months lagged variables does not capture the investment decision choice. In the short run, we see that ice roads are not statistically significant in the drilling activities in the North Slope. A simple explanation is that operating companies have invested more to produce from certain pads by installing gravel roads. Another way for the operators to reduce their dependency on the seasons is by stockpiling and limiting the rig movement within the field.

The model estimates for the long-run that a 1% decrease in oil prices would result in an increase of 0.866% of rigs deployed in the North Slope. Similarly, a 1% decrease in production would see an increase of 1.1% of rigs deployed. This is contradictory to the initial expectation that an increase in oil prices and production would result in increased investment decision to drill and both variables are statistically significant at the 1% and 5% level.

This could indicate that the investment decision in Alaska behaves closer to decision investment of national oil companies (NOCs) as compared to international oil companies (IOCs) where the price of oil has the opposite effect in the long-run as there are other factors that matter more than maximizing profit decision. This could be attributed to long contracts set between the state government and the individual companies that could involve legal obligations in infrastructure, mainly to have enough throughput in the Trans-Alaska pipelines, and other environmental regulations. One other factor to consider is that MAPA provides incentive to produce even at lower oil prices. The tax credit decreases as prices increases, it is intentionally designed to reduce the tax level at lower prices and incentivizes production for the operating companies.

6.3 Results of ice roads effect on exploration activities in the North Slope

The key results from Eq.(4) is listed in Table 4, where short-run and long-run coefficient estimates are shown in Panel A and B with Panel C displaying the diagnostic statistics. The optimal lag length of 1 is selected by the Akaike Information Criterion.

**Table 4: Full Information Estimate of ARDL Eq. (4)**

Panel A: Short-Run Coefficient Estimates

| Lag Order | 0 |
|---|---|
| Δ (Neg) | -2.715 |
| | (1.848) |
| Ice road | 1.122*** |
| | (0.171) |
| ACES | -0.265 |
| | (0.178) |

Panel B: Long-Run Coefficient Estimates

| Constant | Pos | Neg | Production |
|---|---|---|---|
| 16.582* | 3.285** | 1.357 | -1.496* |
| (9.143) | (1.641) | (1.949) | (0.815) |

Panel C: Diagnostic Statistics

| F-statistics | $EC_{t-1}$ | LM |
|---|---|---|
| 41.297 | -0.808 | 1.497 |
| | (0.062) | |

*Notes: Numbers inside parentheses are the std errors. The upper critical bound value of the F-statistics at the 5% significance level is 5.07. LM is the Breusch-Godfrey serial correlation LM test and EC represents an error-correction term. ***,** and * represents significance at the 1%,5% and 10% levels respectively.*

The F-statistics is at 41.297, significantly higher than the upper critical value of 1% of 6.36, indicating that the null hypothesis that exploration wells, *pos*, *neg* and production are not co-integrated can be rejected in favor of cointegration. This supports that there is a long-term relationship amongst the variables even if the variables deviate in the short run. The results of the Lagrange Multiplier (LM) test of residual serial correlation (p-value = 0.22) is satisfactory and we fail to reject the null hypothesis of no serial correlation at 1 lag.

From Panel A, the coefficient for the key variable *neg* is negative as expected, however is statistically insignificant. This suggests that while changes in oil prices affects overall drilling in Alaska, it does not affect exploration in the North Slope. Similarly, we find that the coefficient estimates for ACES contribute negatively for the number of exploration wells yet is statistically insignificant for the duration that the bill was in place. We find that ice road is statistically significant in the short-run and that an extra month of ice road season predicts an extra 1.122 exploration wells spudded.

As for the long run as shown in Panel B, both positive changes in oil prices and production are statistically significant. In the long run, we estimate that a positive change in WTI oil prices increases the number of exploratory wells by 3.285. This positive relationship is easily explained as that individual companies would likely invest in exploring and developing new wells if the prospect of oil prices is high. Likewise, a decrease in production by 1% increases exploratory wells by 1.496 wells. This is expected, as producers would likely venture out and assess new fields to tap into more reservoirs if their production is declining.

# Chapter 7 Summary and Conclusions

In this thesis, we explored the impact of oil prices, production, ice roads and Alaska's oil policy on drilling activities in the North Slope utilizing the ARDL model for the analysis.

For overall drilling in the North Slope, we present the case that oil prices are not significant in the short-run and has a negative relationship with investment decision to drill in the long run. In terms of production, we see that it is positive in the short-run, and negative in the long run. Along with a positive and statistically significant relationship with MAPA, this suggests that decision to invest in drilling in the North Slope is highly affected by this Senate Bill which rewards operating companies with higher tax credits at a lower oil price. Operating companies are incentivized to produce more at lower oil prices, hence, a lower production would result in companies drilling to produce more at lower oil prices. In the short run, it is shown that previous rig counts effects the current rig count, solidifying the notion that sunk cost in infrastructure effects future investment decision.

While we see that ice roads do not affect the overall drilling activities in Alaska, it is clear that the ice roads which are required for inexpensive transportation and is only available during a short season during the year plays a significant part in the decision to explore new fields in the North Slope. A reduction in ice road travel days would mean operating companies are unable to assess new locations which in turn could reduce the development of a field. Ironically, the finding is a Catch 22 – the oil industry is said to contribute greatly to climate change, the same climate change which could see the reduction in exploration in the Arctic due to warming.

Both ACES and a negative change in oil prices is not statistically significant in operating companies decision to invest in exploration well, suggesting that companies take the opportunity to explore new fields, even if prices are low. While ACES is not statistically significant, the estimated coefficient is negative, suggesting that unlike MAPA, ACES is detrimental in exploration levels. In the long run, companies are more likely to invest in exploration wells if prices of oil go up and production declines.

One limitation of this study is concrete figures on the true cost of investment made to actually drill in the North Slope. While estimates of the cost of ice road are available from literature, it was not used in this study as it would require a full mapping of previous years to truly understand the full investment cost to spud an exploration well. Further study would need to be developed to understand the determinants of investment in Alaska such as cost of steel for the pipes and to compare the cost of drilling in Alaska as compared to drilling anywhere else. Future study should study each field individually to account for appraisal lags that could explain the lag between the price of oil and the decision to invest.

## Bibliography

Alaska Department of Natural Resource. (2017). *TAPS Throughput Barrels per Day 1977-2017.* Anchorage: Division of Oil and Gas.

Alaska Department of Revenue. (2018a). *Production History and Forecast.* State of Alaska, Tax Division. Alaska Department of Revenue.

Alaska Department of Revenue. (2018b). *Annual Report 2018.* Annual Report, State of Alaska, Tax Division, Anchorage.

Baker Hughes. (2019, April). *Baker Hughes Rig Count.* Retrieved from Baker Hughes Rig Count: https://rigcount.bhge.com/na-rig-count

Berman, M., & Schmidt, J. (2018). *Economic Effects of Climate Change in Alaska.* Anchorage: Institute of Social and Economic Research.

Chen, F., & Linn, S. C. (2017). Investment and operating choice: Oil and natural gas futures prices and drilling activity. *Energy Economics*, 54-68.

ConocoPhillips Alaska. (2018, October). *NSSI* . Retrieved from North Slope Science Initiative: http://nssi-test.gina.alaska.edu/catalog/entries/8928-2018-19-winter

Department of Labor and Workforce Development. (2018). *Quarterly Census of Employment and Wages.* Juneau: Research and Analysis.

Ghosray, A., & Johnson, B. (2010, February). Trends in world energy prices. *Energy Economics, 32*, 1147-1156.

Guettabi, M. (2018). *How do oil prices influence Alaska and other energy dependent states?* Anchorage: Institute of Social and Economic Research.

Khalifa, A., Caporin, M., & Hammoudeh, S. (2017, February 6). The relationship between oil prices and rig counts: The importance of lags. *Energy Economics, 63*, 213-216.

Leighty, W., & Lin, C. (2012). Tax policy can change the production path: A model of optimal oil extraction in Alaska. *Energy Policy*, 759-744.

Masterson, D. (2009). State of the art of ice bearing capacity and ice construction. *Cold Regions Science and Technology*, 99-112.

McChesney, R. (2018, April 30). Oil prices are up, now what? Fairbanks, Alaska: Daily News-Miner.

McNeely, S. M., & Shulski, M. D. (2011). Anatomy of a closing window: Vulnerability to changing seasonality in Interior Alaska. *Global Environment Change*, 464-473.

Reimer, M. N., Guettabi, M., & Tanaka, A.-L. (2017). Short-run impacts of severance tax change: Evidence from Alaska. *Energy Policy*, 448-458.

Tappen, S. (2014). *Can Tax Policy Change Exploration Levels? A Case of Alaska Oil Legislation.* Master Thesis, University of Alaska Fairbanks, School of Management, Fairbanks.

Weissler, L. (2017). *Alaska's Oil and Gas Production Tax - Tax Credits History.* Summary Report, AOGA.

Wilkerson, C. (2015). How Will Oklahoma Be Affected by the Decline in Oil. *The Oklahoma Economist*.